ELSEVIER

Neuroscience Letters 194 (1995) 69–72

NEUROSCIENCE LETTERS

Vestibular experiences of humans during brief periods of partial sensory deprivation are enhanced when daily geomagnetic activity exceeds 15–20 nT

M.A. Persinger*, P.M. Richards

Behavioral Neuroscience Laboratory, Department of Psychology, Laurentian University, Sudbury, Ontario, P3E 2C6, Canada

Received 17 February 1995; revised version received 9 June 1995; accepted 9 June 1995

Abstract

The intensity of reported vestibular experiences by normal volunteers ($n = 127$, over a 4-year period) increased significantly in a step-like manner during partial sensory deprivation when the daily geomagnetic activity exceeded about 15 nT; the effect size was equivalent to a correlation of about 0.33. Post hoc analyses indicated that the geomagnetic activity during the 3-h period at the beginning of the previous sleep cycle was the single greatest contributor. The enhanced occurrences of experiences that are similar to those associated with complex partial epileptic seizures suggests that specific stimuli associated with geomagnetic activity above about 15 nT affects specific regions of the human brain; the vulnerability occurs during the subsequent 24 h. However, in non-epileptic individuals these experiences must be amplified neurocognitively by removing input from auditory and visual modalities.

Keywords: Geomagnetic activity; Vestibular experiences; Sensory deprivation; Threshold effects; Brain; Human electrical lability; Nocturnal conditions

All living systems are immersed in the earth's magnetic field and are subject to its daily variations. Analyses from several laboratories have suggested a systematic, temporal association between decreased thresholds for microseizure-like electrical activity within specific regions of the temporal lobes of the human brain and the intensity of the variation in daily geomagnetic activity. Persinger [13] and Randall and Randall [21] found that bereavement hallucinations, that were similar in content to those elicited by surgical stimulation [3,5], were more likely to occur during periods of increased geomagnetic activity. Other researchers [6,20] have reported that the quantitative incidence of tonic-clonic convulsions in epileptic patients, a less inferential measure of a decrease in electrical seizure thresholds, also increased during periods of enhanced geomagnetic activity.

Several groups of neuropsychologists [17,18,26] have suggested that the discrete endpoints, such as convulsions or hallucinations, are extremes of a continuum of limbic lability. Empirical support for this concept was reported by Babb et al. [2] who demonstrated that the progression from temporal lobe-specific subjective experiences, such as strangeness or vibrations, to disruption in consciousness (and ultimately convulsions), was a function of the numbers of monitored neurons that were recruited during a focal paroxysmal discharge.

One of the most common precursors and concomitants of complex partial epileptic seizures are vestibular experiences [10,14,15,19,22]. Similar phenomenology, that includes sensations of spinning, vibrations moving through the body and dizziness, are reported by non-epileptic individuals who display complex partial epileptic-like signs (CPELS) and symptoms [17,18]; these individuals exhibit greater variability in the duration of alpha rhythms and the numbers of non-pathological spikes over the temporal lobes [10]. Until recently, these experiences and their association with CPELS were so subtle that they were masked by competing stimuli from auditory and visual modalities [16,25]. However, if input from these modalities are attenuated (by placing goggles over the person's eyes and by sitting in an acoustic chamber) and weak anistropic burst-firing magnetic fields (1 μT) are activated

* Corresponding author, Fax: +1 705 6754824.

0304-3940/95/$09.50 © 1995 Elsevier Science Ireland Ltd. All rights reserved
SSDI 0304-3940(95)11729-D

along the left or right temporoparietal region [19,25], subjective experiences are amplified.

The following experiment was designed to discern if increases in the intensity of ambient geomagnetic activity would specifically increase the incidence and intensity of vestibular experiences in normal subjects. Because there is no a priori reason to assume linearity between these measures, the index of daily average geomagnetic activity (aa values, measured in nT, as described by Mayaud [12]) was divided into specific increments: 0–15 nT, 16–30 nT, 31–45 nT, and >45 nT (data obtained from the Geomagnetic Indices Bulletin, National Geophysical Data Center, Solar-Terrestrial Physics Division, E/CG2, 325 Broadway, Boulder, CO 80303, USA). The increments were selected on the bases of empirical data. Several researchers [4,6,11,13,20] have reported that increases in seizure probability and disruption of the normal neuroelectrical stability of limbic structures begins to emerge when the daily aa values exceed approximately 20 nT. We have found that the magnitude of the daily averages from the most proximal magnetographic observatories (Fredricksburg, Ottawa) are very strongly correlated (0.90) and exhibit regression slopes that approach 1.00.

Over a 4-year period (1989, 1990, 1991, 1993), a total of 51 men and 76 women, between the ages of 18 and 30 years, served as subjects. They were all enrolled in first or second year university arts courses and received a 2% bonus mark for participation; they were told that the experiment was involved with relaxation. On the day of the experiment, each subject sat in a comfortable arm chair that was housed within a commercial acoustic chamber. After goggles had been placed over the eyes, a modified motor cycle helmet was placed over the subject's head. Along each side of the helmet, four solenoids were embedded through which the field pattern, generated by a computer, was presented. The magnetic field structure simulated burst-firing of neurons and was less than 1 μT within the region occupied by the temporal lobes of the subject. The technical description of the equipment and the protocol have been reported elsewhere [25].

During the 30-min experiment, the subject sat within the quiet environment; the only light that could be discerned through the opaque goggles was from a red photographer's lamp (about 1 lx) directly in front of the subject. Usually the magnetic field was (twice) activated for 10 min once every 15 min during the experiment. About one-third of the men and one-third of the women received the fields either along the right side of the brain, left side of the brain or across the entire brain (these three conditions were distributed randomly over the 4-year period). Each subject was tested only once.

At the end of the experiment the subject completed an Exit Questionnaire. It contained 20 items [16] that reflect the most common experiences (e.g. feeling the sense of a presence, thoughts from childhood, visual sensations, odd smells, vibrations); the potential score for each item was 0 = did not occur, 1 = occurred at least once, 2 = occurred frequently. Neither the experienced technicians nor the subjects were familiar with the hypothesis or the primary design of the general experiment. Because normal subjects' CPELS are correlated with vestibular experiences within this setting and could consequently mask or add variability to any weak environmental (geomagnetic) effect, each subject's CPELS score was obtained from the master data base. All analyses involved SPSS software on a VAX 4000 computer.

The 20 items were first factor analyzed (PA1) in order to discern the primary sources of variance. Six factors (explaining a total of 61% of the variance) emerged that reflected themes of: fear and odd sensations (eigen value = 4.07), out-of-body-like and dream experiences (eigen value = 1.50), vestibular experiences (eigen value = 1.45), a sense of a presence (eigen value = 1.25), anger-sadness (eigen value = 1.09) and odd tastes and thoughts from childhood (eigen value = 1.06).

Two-way analyses of variance for each of the six factors as a function of the increment of geomagnetic activity on the day of the experiment and sex showed, as hypothesized, that only the vestibular factor was significantly associated with geomagnetic activity ($F(3,117) = 3.73$, $P < 0.01$; $\eta = 0.29$). Covariance for the subjects' scores for CPELS (grand mean and SD = 30% and 17%, respectively) before this analysis retained the geomagnetic effect ($F(3,116) = 4.01$, $P < 0.01$; $\eta = 0.30$). There was also no statistically significant differences ($P > 0.05$) between the groups who received stimulation

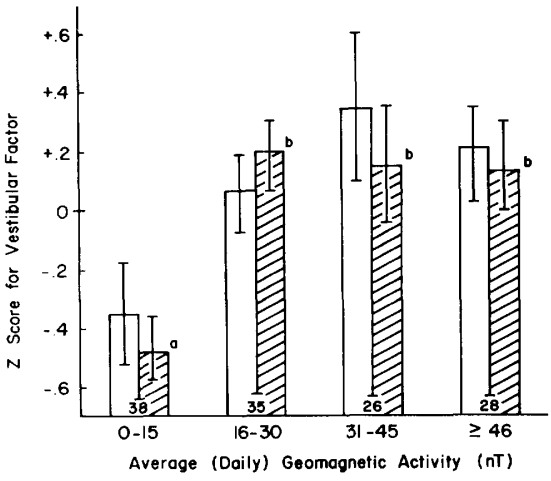

Fig. 1. Z scores for the factor that was loaded by vestibular experiences within the experimental setting as a function of the increment of global geomagnetic activity (in nanoTesla) during the first half of the day. Vertical bars indicate standard error of the mean (SEM) and numbers within the bars indicate numbers of subjects. Open bars, raw z scores; diagonal bars, z scores after covariance for complex partial epileptic-like signs.

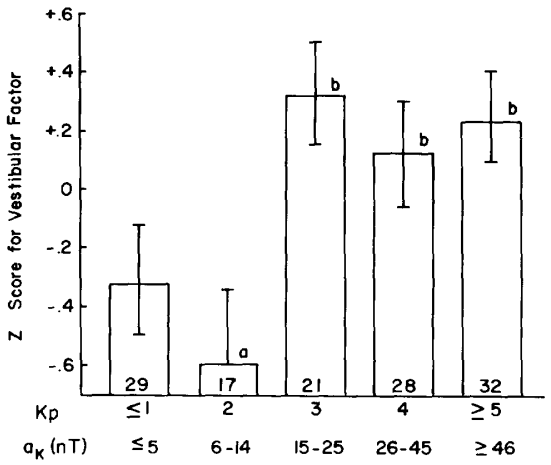

Fig. 2. Z scores for the vestibular factor for increasing increments of geomagnetic activity during the approximate local period of 2000–0100 h (the night before the experiment). Numbers of subjects per increment are indicated.

over either the left, right, or both temporal lobes for any of the factors.

Post hoc analyses (Tukey set at $P < 0.05$) indicated that the major source of the difference was between the scores for vestibular experiences on the days when the geomagnetic activity exceeded 15 nT compared to those days when the variations were less than this value (Fig. 1); the effect was particularly evident when the effects of the subjects' CPELS were removed (covaried) before the group comparisons. There was no significant difference between the four increments of geomagnetic activity or gender and the vestibular experiences for either the day after or for each of the 3 days before the day of the experiences. None of the interactions between sex and geomagnetic activity were statistically significant.

To discern which specific 3-h increment was most associated with the vestibular experiences within the experimental setting, one-way analyses of variance were completed for this factor score as a function of the 3-h Kp (Geomagnetic Indices Bulletin) values (0, 1 collapsed into 1; >5 was collapsed into 5; otherwise the values were the same). The only significant effect occurred for the 3-h Kp value between 00 and 0300 UT ($F(4,116) = 3.36$, $\eta = 0.32$), which corresponded to approximately local time of 2000 h to 0100 h (Fig. 2). Covariance for CPELS did not change this difference ($F(4,115) = 4.14$, $P < 0.001$; $\eta = 0.34$).

The results of this study support hypotheses that have been suggested or developed by several researchers. First, there appears to be an all-or-none threshold for the intensity of vestibular experiences during increased geomagnetic activity; in this instance the threshold is about 15–20 nT; activity above this level has been temporally associated with disruption or interference with: (a) pigeon behavior [28]; (b) survival following the induction of limbic seizures [4]; (c) cardiovascular stability [11]; and (d) phenomenological experiences that may have been discerned because of the enhanced signal/noise ratios associated with reductions of neuroelectrical perturbations within limbic system [17]. Geomagnetic perturbations that are superimposed upon local static field anomalies may be particularly disruptive [7].

Secondly, the strongest relationship between the vestibular experiences and geomagnetic activity was associated with its values during the night before the day of the experiment. This observation is commensurate with the assumption that disruptions in the normal circadian cycle, such as the first stages of sleep, can alter the electrical lability of the brain during the subsequent day [9]. Third, the primary effect from geomagnetic activity during the previous night would be compatible with the suppressive effects of experimental magnetic fields upon nocturnal levels of the brain's endogenous anticonvulsant, melatonin [1,18,23,24,28]. Recent experimental work [27] with complex magnetic fields whose strengths vary within the nT range has shown effects on both arousal and vestibular sensations.

The fact that only the vestibular experiences were significantly correlated with geomagnetic activity indicates a specificity of effect despite the subjectivity of the endpoint. Experiences of vibrations moving within the body are frequent correlates of patients who also exhibit complex partial seizures [3]. These sensations may reflect a continuum of temporal lobe sensitivity that extends through the normal population [16]. Traditional concepts of neurofunction suggest that the medial surface of the transverse gyri of the superior gyrus of the temporal lobes, which are functionally associated with the amygdala and the anterior hippocampus, may be an important structural correlate of these experiences.

[1] Arendt, J., Melatonin and the pineal gland. In J. Arendt, D.S. Minors and J.M. Waterhouse (Eds.), Biological Rhythms in Clinical Practice, Wright, London, 1989, pp. 184–206.
[2] Babb, T.L., Wilson, C. L. and Isokawa-Akesson, M., Firing patterns of human limbic neurons during stereoencephalography (SSEG) and clinical temporal lobe seizures, Electroencephalogr. Clin. Neurophysiol., 66 (1987) 467–482.
[3] Bancaud, J., Brunet-Bourgin, F., Chauvel, P. and Halgren, E., Anatomical origin of deja vu and vivid 'memories' in human temporal lobe epilepsy, Brain, 117 (1994) 71–90.
[4] Bureau, Y.R.J. and Persinger, M.A., Geomagnetic activity and enhanced mortality in rats with acute (epileptic) limbic lability, Int. J. Biometeor., 36 (1992) 226–232.
[5] Gloor, P., Temporal lobe epilepsy: its possible contribution to the understanding of the functional significance of the amygdala and of its interaction with neocortical-temporal mechanisms. In B.E. Eleftheriou (Ed.), Advances in Behavioral Neurobiology: The Neurobiology of the Amygdala, Plenum Press, New York, 1972, pp. 423–457.
[6] Keshavan, M.S., Gangadhar, B.N., Gautam, R.U., Ajit, V.B. and Kapur, R.L., Convulsive threshold in humans and rats and magnetic field changes: observations during total solar eclipse, Neurosci. Lett., 22 (1981) 205–208.

[7] Kirschvink, J.L., Dizon, A.E. and Westphal, J.A., Evidence from strandings for geomagnetic sensitivity in cetaceans, J. Exp. Biol., 120 (1986) 1–24.
[8] Lerchl, A., Honaka, K.O., Reiter, R.J., Pineal gland 'magnetosensitivity' to static magnetic fields is a consequence of induced electric currents (eddy currents), J. Pineal. Res., 10 (1991) 109–116.
[9] Luce, G.G., Biological rhythms in psychiatry and medicine, US Dept. Health Education and Welfare, MD, 1970, pp. 60–183.
[10] Makarec, K. and Persinger, M.A., EEG validation of a temporal lobe signs inventory in a normal population, J. Res. Person., 24, 1990, 323–337.
[11] Malin, S.R.C. and Srivastava, B.J., Correlation between heart attacks and magnetic activity, Nature, 227 (1979) 646–648.
[12] Mayaud, P.N., A hundred year series of geomagnetic data: indices aa, storm sudden commencements, IAGA Bul., 33 (1973) entire volume.
[13] Persinger, M.A., Increased geomagnetic activity and the occurrence of bereavement hallucinations: evidence for melatonin-mediated microseizuring in the temporal lobe? Neurosci. Lett., 88 (1988) 271–274.
[14] Persinger, M.A., Vectorial cerebral hemisphericity as differential sources for the sensed presence, mystical experiences and religious conversions, Percept. Motor Skills, 76 (1993) 915–930.
[15] Persinger, M.A., Near death experiences: determining the neuroanatomical pathways by experiential patterns and simulation in experimental settings. In L. Bessette (Ed.), Healing: Beyond Suffering and Death, MHH, Quebec, 1993, pp. 227–286.
[16] Persinger, M.A., Koren, S.A., Makarec, K., Richards, P. and Youlton, S., Differential effects of wave form and the subject's possible temporal lobe signs upon experiences during cerebral exposure to weak intensity magnetic fields, J. Bioelec., 10 (1991) 141–184.
[17] Persinger, M.A. and Krippner, S., Experimental dream telepathy, clairvoyance and geomagnetic activity, J. Am. Soc. Psychic Res., 83 (1989) 101–116.
[18] Persinger, M.A. and Makarec, K., Temporal lobe epileptic signs as a continuum from normals to complex partial epileptics: normative data and special populations, J. Clin. Psychol., 40 (1993) 33–45.
[19] Persinger, M.A., Richards, P.M. and Koren, S.A., Differential ratings of pleasantness following right and left hemispheric application of low energy magnetic fields that stimulate long-term potentiation, Int. J. Neurosci., in press.
[20] Rajaram, M. and Mitra, S., Correlations between convulsive seizure and geomagnetic activity, Neurosci. Lett., 24 (1981) 187–191.
[21] Randall, W. and Randall, S., The solar wind and hallucinations – a possible relation due to magnetic disturbances, Biolectromagnetism, 12 (1991) 76–70.
[22] Remilard, G.M., Andermann, F., Testa, G.F., Gloor, P., Aube, M., Martin, J.B., Feindel, W., Guberman, A. and Simpson, C., Sexual ictal manifestations predominate in women with temporal lobe epilepsy: a finding suggesting sexual dimorphism in the human brain, Neurology, 33 (1983) 323–330.
[23] Reiter, R.J., Alterations of the circadian rhythm by the electromagnetic spectrum: a study in environmental toxicology, Reg. Tox. Pharmacol., 15 (1992) 226–244.
[24] Reiter, R.J., Static and extremely low frequency electromagnetic field exposure: reported effects on the circadian production of melatonin, J. Cell. Biochem., 51 (1993) 394–403.
[25] Richards, P.M., Persinger, M.A. and Koren, S.A., Modification of activation and evaluation properties of narratives by weak complex magnetic field patterns that simulate limbic burst firing, Int. J. Neurosci., 71 (1993) 71–85.
[26] Roberts, R.J., Gorman, L.L., Lee, G.P., Hines, M.E., Richardson, E.D., Riggle, T.A. and Varney, N.R., The phenomenology of multiple partial seizure-like symptoms without stereotyped spells: an epilepsy spectrum disorder? Epilepsy Res., 13 (1992) 167–177.
[27] Sandyk, R., Successful treatment of multiple sclerosis with magnetic fields, Int. J. Neurosci., 66 (1992) 237–250.
[28] Zeise, M.L and Semm, P., Melatonin lowers excitability of guinea pig hippocampal neurons in vitro, J. Comp. Physiol. A, 157 (1988) 23–29.